# Potassium Requirements for Maximum Yield and Quality of Processing Tomato

By T.K. Hartz

California is the leader in processing tomato production, growing nearly 40 percent of world supply. The majority of fruit is processed into concentrated paste, but an increasing percentage is being used for products utilizing peeled fruit, either whole or diced. Important fruit quality attributes for paste production are soluble solids content (SS) and color of the blended product. Uniformity of color is more important for peeled fruit. Even a small area of poorly colored tissue is problematic.

> Maximizing the color of tomatoes for peeling clearly required greater potassium (K) supply than that required for maximum fruit yield.

Uneven ripening of processing tomato fruit is a common problem in California. The typical external symptom, called yellow shoulder (YS), is a ring of tissue around the stem scar that upon ripening remains yellow. Internal white tissue (IWT), which can occur throughout the fruit, is often severe enough to render affected fruit unsuitable for use in peeled, diced products. The occurrence of these disorders has been frequent, but unpredictable.

Potassium nutrition has often been linked to tomato fruit yield and quality, but its relative influence on tomato fruit yield and quality under typical California field conditions is less clear. Exchangeable soil K is generally high, commonly greater than 150 parts per million (ppm), a level which numerous field trials have shown to be adequate to achieve maximum yield. Factors other than K fertility (primarily irrigation management) predominately control fruit soluble solids.

To systematically determine the influence

**TABLE 1.** Correlation of soil and plant characteristics with tomato fruit quality attributes.

| | Exchangeable soil cations, meq/kg | | | K activity | K/√Mg | K concentration, % | |
|---|---|---|---|---|---|---|---|
| | K | Ca | Mg | ratio[3] | ratio | leaf | fruit |
| Leaf K, g/kg | .25[2] | .01 | -.14 | .29[2] | .25[2] | – | .19[1] |
| Fruit K, g/kg | .54[2] | .33[2] | -.40[2] | .55[2] | .64[2] | .19[1] | – |
| Soluble solids, °Brix | .23[2] | .19[1] | -.02 | .20[1] | .24[2] | .28[2] | .09 |
| Blended color | .02 | .15 | .00 | -.02 | .04 | -.11 | .09 |
| Yellow shoulder, % of fruit | -.34[2] | -.05 | .36[2] | -.38[2] | -.41[2] | -.22[2] | -.35[2] |
| Internal white tissue, % | -.33[2] | -.04 | .30[2] | -.36[2] | -.38[2] | -.17[1] | -.32[2] |
| Total color disorders, %[4] | -.38[2] | -.07 | .35 | -.42[2] | -.45[2] | -.19[1] | -.38[2] |

[1]and [2] Correlation significant at $p < 0.05$ or 0.01, respectively.
[3]$K/\sqrt{Ca + Mg}$, on a soil exchangeable meq/100 g basis.
[4]% of fruits expressing either YS or IWT.

of K nutrition on processing tomato quality, a survey of 140 tomato fields was conducted during 1996 and 1997. Fields were chosen to represent the geographical range of production in central California, a variety of soil types, and harvest dates from early July through late September. To minimize cultivar effects, all fields monitored were planted in either 'Halley' or 'Heinz 8892'. These cultivars represented nearly 50 percent of processing tomato production in California in 1997.

Composite soil (top 12 inches) and whole leaf samples (recently expanded leaves, at full bloom growth stage) were collected in each field. Soil was analyzed for ammonium acetate exchangeable K, calcium (Ca) and magnesium (Mg), leaf tissue for K, Ca, and Mg concentrations. Fruit samples were collected just prior to commercial mechanical harvest. A subsample of fruit was mechanically juiced and analyzed for SS (° Brix, by refractometer) and color. Remaining fruit were scored for the number showing YS or IWT. Yellow shoulder was evaluated externally, IWT internally on fruit cut longitudinally.

Exchangeable soil K and soil cation balance were correlated with the tomato fruit color disorders YS and IWT, but had little effect on other fruit quality factors (**Table 1**). Exchangeable K, whether expressed as meq/100 g or as K activity ratio ($K/\sqrt{Ca + Mg}$, on a milliequivalent basis), was negatively correlated with the incidence of both YS and IWT.

Exchangeable Mg was positively correlated with, while exchangeable Ca was unrelated to, the disorders. The soil $K/\sqrt{Mg}$ ratio was more closely correlated with the percentage of total color disorders (YS or IWT) than was either exchangeable K or K activity ratio. The practical significance of the relationship of soil cation balance and fruit color disorders was greater than the modest correlations would suggest. Fields with less than 0.7 meq/100 g exchangeable K showed a wide range of color disorder severities, with an average of 20 percent of fruit affected. Conversely, fields with greater than 0.7 meq/100 g exchangeable K averaged only 7 percent color disorders. Fields with soil $K/\sqrt{Mg}$ greater than 0.25 averaged only 4 per-

**TABLE 2.** Effect of soil amendment with gypsum and K on tomato fruit yield and quality.

| Soil treatment | Total fruit yield, tons/A | Soluble solids, ° Brix | Blended color[1] | Color disorders, % of fruit: YS | IWT | Total |
|---|---|---|---|---|---|---|
| Davis | | | | | | |
| unamended control | 47.1 | 4.5 | 22.8 | 9 | 8 | 13 |
| 2 tons gypsum/A | 46.7 | 4.5 | 23.1 | 6 | 6 | 9 |
| 4 tons gypsum/A | 45.3 | 4.5 | 22.5 | 5 | 5 | 8 |
| 200 lb $K_2O$/A | 45.8 | 4.6 | 23.0 | 6 | 7 | 9 |
| 400 lb $K_2O$/A | 48.9 | 4.5 | 22.9 | 7 | 5 | 9 |
| 4 tons gypsum + 400 lb $K_2O$/A | 47.1 | 4.5 | 22.7 | 5 | 4 | 6 |
| Contrasts | | | | | | |
| gypsum vs. control | ns | ns | ns | ** | ns | ** |
| K vs. control | ns | ns | ns | * | ns | * |
| combination treatment vs. control | ns | ns | ns | * | * | ** |
| Clarksburg | | | | | | |
| unamended control | 41.3 | 4.3 | 24.5 | 14 | 16 | 21 |
| 200 lb $K_2O$/A | 42.2 | 4.4 | 23.3 | 8 | 7 | 11 |
| 400 lb $K_2O$/A | 41.8 | 4.3 | 24.5 | 9 | 8 | 12 |
| Contrast | | | | | | |
| K vs. control | ns | ns | ns | ns | * | * |

[1]Dimensionless unit, lower value indicates more intense red.
ns, *, ** Not significant, or significant at $p<0.05$ or 0.01, respectively.

cent color disorders. Potassium concentration in tomato fruit was more closely correlated with the soil $K/\sqrt{Mg}$ ratio than with exchangeable K. Exchangeable K was weakly correlated with fruit SS, but the slope of the regression relationship suggested that the impact of soil K level on SS was minor.

To document the connection between soil K status and tomato color disorders, two field trials were conducted in 1996. A site located at the University of California Vegetable Crop Research Center, Davis (UCD), was chosen which had a moderate K status (324 ppm extractable K, $K/\sqrt{Mg}$ ratio of 0.24). The other site, in Clarksburg, had much more limited K (137 ppm K, $K/\sqrt{Mg}$ of 0.08). At Davis, gypsum was fall-applied in replicated plots at 2 or 4 tons/A to dissolve with winter rains and displace some Mg. Prior to spring planting, K fertilizer at 200 or 400 lb $K_2O$/A was incorporated into the beds. At Clarksburg, replicated rates of either 200 or 400 lb $K_2O$/A were banded on the bed tops shortly after stand establishment, so the K would be moved into the root zone with the season-long sprinkler irrigation.

The fertilization trials confirmed the link between soil cation balance and the occurrence of YS and IWT (**Table 2**). At Davis, both the application of gypsum and K fertilization significantly decreased YS and total color defects. The combination of gypsum and K reduced total color disorders by 54 percent. Soil K application at Clarksburg significantly decreased IWT and total color disorders. Yellow shoulder and IWT incidence was higher at Clarksburg than at UCD, as the more adverse soil cation balance predicted. At neither site was fruit yield, SS, blended color, or leaf or fruit K concentration significantly affected by soil treatment.

The modest correlation between soil K and these color disorders in the field survey emphasized that soil extractable K is a useful, but imperfect, indicator of K availability. Factors such as soil physical characteristics (structure, compaction, aeration, etc.) and management practices that influence root density and function (most notably irrigation method, timing and volume) can affect K phytoavailability, since crop K uptake is a diffusion rate-limited process.

**Dr. T. K. Hartz** is shown examining plants in a California tomato field.

It is widely recognized that crop K uptake is affected by the activity of other soil cations. This study found that soil Mg had greater influence on crop K status, YS, and IWT than did soil Ca. Soil $K/\sqrt{Mg}$ ratio was the variable most closely correlated to fruit K concentration and the incidence of color disorders. Soil application of gypsum at the Davis site reduced color disorders, apparently by reducing exchangeable Mg, since soil exchangeable K was virtually unaffected.

The field trials showed that high levels of amendment may be required to substantially reduce fruit color disorders. This would particularly be true of soils with high K fixation capacity. Since no yield advantage would be expected if a soil had greater than 0.3 meq/100 g exchangeable K, it would be cost prohibitive to amend problem soils unless a significant premium was paid for improved fruit quality for peeling.

Despite the uncertainty regarding factors other than K that contribute to YS and IWT development, it is clear that K plays a dominant role. Only two of the 45 fields with soil $K/\sqrt{Mg}$ greater than 0.25 had significant levels of color disorders. This relationship will allow the processing tomato industry to use routine soil testing to rank fields for the relative danger of encountering severe YS and IWT expression and to suggest appropriate soil amendment strategies. BC

*Dr. Hartz is Vegetable Crops Specialist, Department of Vegetable Crops, University of California, Davis, CA 95616.*